SPATIO-TEMPORAL ANALYSES OF THE DISTRIBUTION OF ALCOHOL OUTLETS IN CALIFORNIA

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Li Li

SPATIO-TEMPORAL ANALYSES OF THE DISTRIBUTION OF ALCOHOL OUTLETS IN CALIFORNIA

The objective of this research is to examine the development of the California alcohol outlets over time and the relationship between neighborhood characteristics and densities of the alcohol outlets. Two types of advanced analyses were done after the usual preliminary description of data. Firstly, fixed and random effects linear regression were used for the county panel data across time (1945-2010) with a dummy variable added to capture the change in law regarding limitations on alcohol outlets density. Secondly, a Bayesian spatio-temporal Poisson regression of the census tract panel data was conducted to capture recent availability of population characteristics affecting outlet density. The spatial Conditional Autoregressive model was embedded in the Poisson regression to detect spatial dependency of unexplained variance of alcohol outlet density. The results show that the alcohol outlets density reduced under the limitation law over time. However, it was no more effective in reducing the growth of alcohol outlets after the limitation was modified to be more restrictive. Poorer, higher vacancy rate and lower percentage of Black neighborhoods tend to have higher alcohol outlet density (numbers of alcohol outlets to population ratio) for both on-sale general and off-sale general. Other characteristics like percentage of Hispanics, percentage of Asians, percentage of younger population and median income of adjacency neighbors were associated with densities of on-sale general and off sale general alcohol outlets.

Some regions like the San Francisco Bay area and the Greater Los Angeles area have more alcohol outlets than the predictions of neighborhood characteristics included in the model.

Aniruddha Banerjee Ph.D., Chair

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INTRODUCTION

The misuse of drinking alcohol represents one of the leading causes of preventable death, illness and injury in many societies throughout the world. Alcohol consumption is associated with a variety of adverse health and social consequences (World Health Organization, 2000).

Multiple public policies such as minimum legal drinking age, taxation and blood alcohol concentration (BAC) limits are adopted by many governments across the world to reduce alcohol consumption and its associated harm. Among these are limitations on the density of alcohol outlets. Regulations on alcohol outlets' density efficiently reduce excessive alcohol consumption and related harmful effects (Nelson et al., 2013). Empirical research has related high densities of alcohol outlets to increased drinking problems, including traffic crashes (Ponicki, Gruenewald, & Remer, 2013), violent assault (Mair, Gruenewald, Ponicki, & Remer, 2013), non-violent crimes (Toomey et al., 2012), and child abuse and neglect (Freisthler, Gruenewald, Remer, Lery, & Needell, 2007). Compared to communities with a lower density of alcohol outlets, communities with higher densities of alcohol outlets experience higher rates of alcohol-related problems. Alcohol availability in a neighborhood also impacts the social, physical, and economic well-being of its residents (Franklin, 2009). Alcohol outlet density explained the most variance of violent crime rates than any other neighborhood socio-demographic variables (Gorman, Speer, Gruenewald, & Labouvie, 2001). Few studies have been conducted, however, on the determinants of local outlet densities.

Alcohol outlet density in this study was defined as the ratio of the number of alcohol outlets to population. California added limitations on the number of licensed premises to its statutes in 1945 which regulate densities of on-sale general and off-sale general licenses. On-sale general licenses authorize the sale of all types of alcoholic beverages: namely, beer, wine and distilled spirits, for consumption on premises, and the sale of beer and wine for consumption off premises. Off-Sale General licenses authorize the sale of all types of alcoholic beverages for consumption off premises in original, sealed containers. The law was modified to reduce the legal limits of on-sale general and off-sale general alcohol license in 1961. The current section 23816 and 23817 of Statutes says:

> **§ 23816. On-sale general licenses** The number of premises for which an on-sale general license is issued shall be limited to one for each 2,000, or fraction thereof, inhabitants of the county in which the premises are situated.
>
> **§ 23817. Off-sale general license** On and after July 1, 1963, the number of premises for which an off-sale general license is issued shall be limited to one for each 2,500, or fraction thereof, inhabitants of the county in which the premises are situated.

The purpose of these laws is described in section 23815 of Statutes as "It is hereby determined that the public welfare and morals require that there be a limitation on the number of premises licensed for the sale of distilled spirits."

The law is applied at the county level in which heterogeneity makes it difficult to find the relationship of alcohol outlets density and neighborhood's characteristics. Increasing the geographic resolution to the census tract level gives more power when studying the spatial distribution of alcohol outlets density.

The goals of this study are:

1. Quantitatively and qualitatively describe dynamic development of on-sale general and off-sale general alcohol outlets over time in California;

2. Assess the effectiveness of Limitation on Numbers of Alcohol Outlet law; that is: how well the law worked;

3. Quantitatively find characteristics like race, ethnicity, age and socio-economic characteristics that determining the on-sale general and off-sale general alcohol outlet density and;

4. Use spatial auto regression to unbiasedly predict on-sale general and off-sale general alcohol outlet density.

METHODOLOGY

Data Source

Three statistical analyses: descriptive statistics, fixed/random effect linear regression and Poisson spatial regression, were conducted in this study. The first analysis describes density of outlets in 58 counties of California from 1941 to 2010. It excludes any population effects that may bias the raw estimation of rates since people who use outlets may cross county boundaries to buy alcohol and hence affect the law's intended purpose. The second analysis deals with density of alcohol outlets over time. The second analysis worked with these 58-county panel data of difference of numbers of alcohol outlets from 1945 to 2010 using the available population counts and race information data from census bureau. The third analyses worked with census tract panel data of numbers of alcohol outlets exposed to population effects from 2001 to 2009. Tract level outlets data was available from 2001-2009.

County level data. The number of alcohol licenses of county for each year was obtained from annual reports of the California Department of Alcoholic Beverage Control (ABC). In the reports, numbers of different alcohol licenses were summarized by county. The license types are assigned differently over time. For example, in 1941, there were 11 types of licenses in which license AP was for on-sale general, license BC was for off-sale general, license APC was for both on-sale general and off-sale distilled spirits. To get the numbers of on-sale general licenses in 1941, it is necessary to add AP and APC together. There are many more types of licenses now. To calculate the numbers of on-sale general in recent years, it is necessary to add license type 47, On-Sale General for Bona Fide Public Eating Place; type 48, On-Sale General for Public Premises; type 53, On-Sale General for Train; type 54, On-Sale General for Boat; type 55, On-Sale General for Airplane; type 56, On-Sale General for Vessel of more than 1,000 tons burden; type 57, Special On-Sale General and type 83, On-Sale General Caterer's License together.

There were some years' data: year 1943, year 1945, year 1949, year 1978 and year 1999, were not available even after conducting detailed primary and secondary data collection using calls, emails, web searches and library resources. Population and race data for each county were obtained from US census data from 1940 to 2010. Annual population and Race data was interpolated between census decennial years. Outlets density is calculated from number of alcohol outlets divided by population.

Census tract level data. Listings of active alcohol licenses were obtained in January of each year from the ABC (alcohol beverage control) database between 2001 and 2009. Outlet locations were geocoded and aggregated to census tracts using the premise addresses listed on each license record in ArcGIS™ software. Ninety five percent of licenses were successfully geocoded. On-sale general outlets (e.g., bars, pubs and restaurants) were included (alcohol premise with any license type of 47, 48, 53, 54, 55, 56 and 57). Even though it didn't cover all license types of on-sale general, they were the most common ones. Off-sale general outlets (e.g., liquor stores, grocery stores) were assigned alcohol license type 21. Demographic and economic variables for census tract neighborhood structural characteristics were extracted from GeoLytics™ (a commercial vendor) estimates. These included race/ethnicity (percentage Black, Asian and Hispanic), age composition (percentage 0-19, 20-24, 25-44 and 45-64), inflation adjusted median household income(x1,000), population density (1000 population per square mile), percentage population below 150% poverty, unemployment rate, vacant house rate, percentage of families with children under 17.

Geographic data were obtained from TIGER/Line Shapefiles of US Census Bureau. A geographic adjacency matrix was applied as the condition for regression in the second statistical analyses. The matrix was from Shapefiles converted to S-PLUS format using R package MapTools, then transformed to a geographic adjacency matrix in WinBUGS. Adjacency matrix contains 1 and 0 which represent contiguity between geographic units.

Dynamic development of alcohol outlet density in counties over time

Descriptive statistics (using county data)

The average of on-sale general outlets for counties in California dropped from 3.8 per 2000 population in 1941 to 1.6 per 2000 population in 2010. The average of off-sale general alcohol outlets dropped from 4.0 per 2500 population in 1941 to 1.4 per 2500 population in 2010. There was no county, except Alpine county, which lacked alcohol outlet(s), with outlet density below current limitations in 1941. By 2010, however, there were 25 counties with on-sale general and 11 counties with off-sale general below legal alcohol density limits. The standard deviation of on-sale general outlets density was 2.15 in 1941 and 2.34 in 2010. When excluding Alpine county, which had an extreme high on-sale general density (understandable due to its large land area and tiny population), the standard deviation was 1.18 in 2010. The standard deviation of off-sale general alcohol density was 2.44 in 1942 and 1.00 in 2010.

Figures 1 and 2 below separately show the average observed on-sale general and off-sale general alcohol outlet density of 58 counties comparing to the legal limits regulated by laws from 1941 to 2010. On-sale general legal density limit was reduced from 1 per 1000 population to 1 per 2000 population in 1961. Off-sale general legal density limit was reduced from 1 per 1000 population to 1 per 2000 population in 1961, and then further down to 1 per 2500 population in 1963. Figures 1 and 2, demonstrate the general trends of on-sale general and off-sale general alcohol licenses were both slowly declining and generally approaching the legal limits over the last six decades, but they still exceeded the limitations in the end.

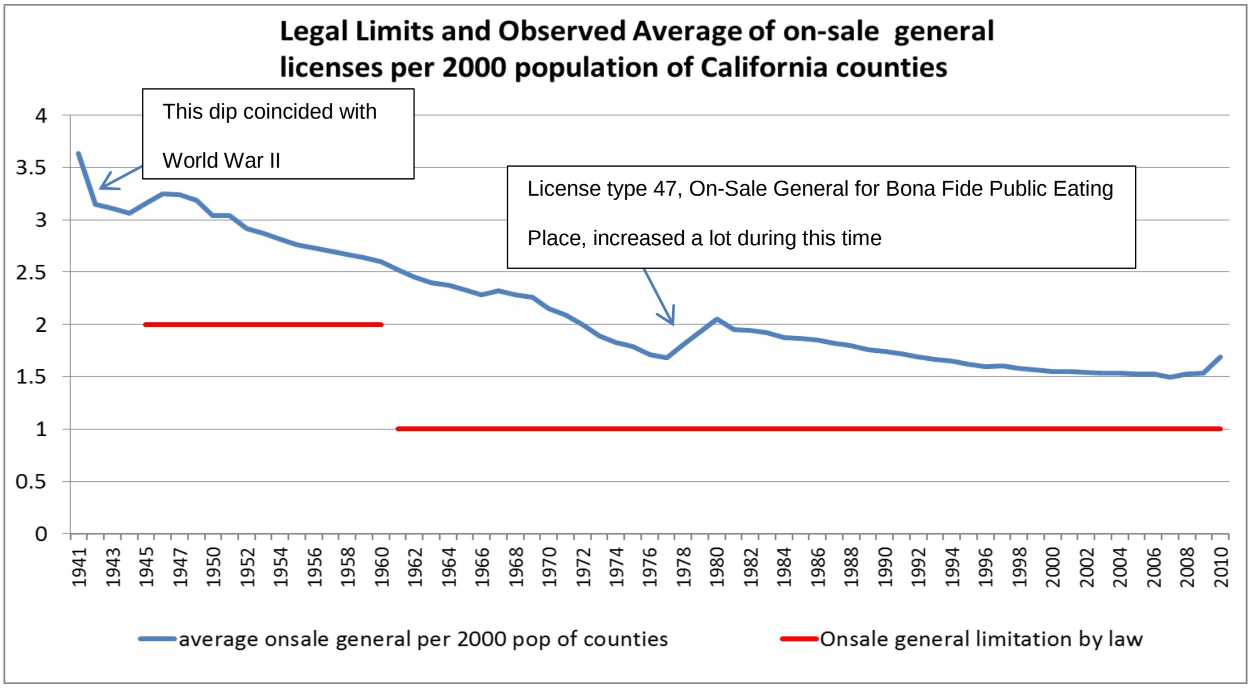


Figure 1- average of on-sale general alcohol outlets density in counties and the limitation from 1941 to 2009

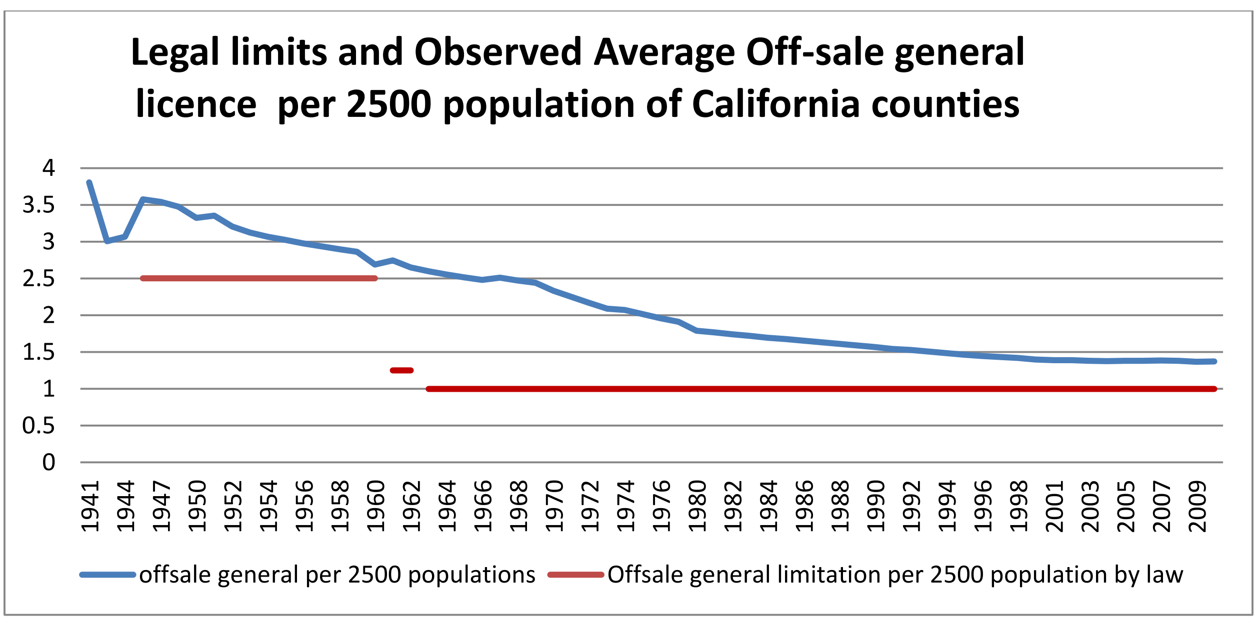


Figure 2 - average of off-sale general alcohol outlets density in counties and the limitation from 1941 to 2010

Fixed and Random Effect Linear Regressions on difference of numbers of alcohol outlets (county data)

To study the change of numbers of alcohol outlets across a long time series, I applied fixed and random effects linear regression analyses to county panel data from 1945 to 2010 for both onsale and offsale outlets. Both fixed and random effects analysis were done to find out which model better explained the effects of the modification of law in 1961. Dependent variables were the respectively differences between years in numbers of on-sale general licenses and off-sale general licenses in a given county. Independent variables were the difference of population, difference of percentage of White and Black residents in a given county between years. A dummy variable with a value of 0 before 1961 and 1 in later years was added to test for a shift in outlet change rates following a modification in the limitation law.

Fixed and random effect linear regression models were estimated in Stata/SE 13.0. Fixed effect model is used when the differences of errors among counties are non-random. It introduces a separate intercept for each county, and although they are unbiased, they tend to be statistically inefficient because the county intercepts add 57 degrees of freedom to this model. The results only tell the impact of variables over time. Random effects models instead use an error component to allow for unexplained differences across counties, which is more efficient but biased if county differences are not randomly distributed. Hausman tests (Maddala, Gangadharrao S., & Kajal Lahiri, 1992) indicated that the fixed effect model was more appropriate for on-sale general licenses regression but the random effect model was a better choice for off-sale general licenses.

Fixed effect On-sale general Difference linear regression model:

$$\mathbf{Y_{it} = \beta_k X_{k,\,it} + \lambda_i + \delta T + \varepsilon\ it}; \qquad \mathbf{(1)}$$

- $\mathbf{Y_{it}}$ is the difference of numbers of on-sale general alcohol outlets in county i in year t comparing to year t-1;
- $\mathbf{X_{k,\,it}}$ represents independent variables: difference of population, the difference of percentage of White population and Black population in county i in year t comparing to year t-1 ;
- $\mathbf{B_k}$ is coefficient of independent variables.
- $\boldsymbol{\lambda_i}$ is the intercept for each county;
- **T** is time as binary post-law variable (dummy), which is 1 after 1961 and 0 during years 1945-1960;
- $\boldsymbol{\delta}$ is the coefficient for the binary time variable;
- $\boldsymbol{\varepsilon}$ **it** is the error term.

The above county-specific fixed effect model was able to reveal the difference change of numbers of on-sale general licenses in each county over time. The county intercepts account for variance between counties not explained by other predictor variables.

The results are reported in RESULTS section.

Random effect off-sale general linear regression model:

$$Y_{it} = \beta_k X_{k,\,it} + \lambda + \delta T + \mu_i + \varepsilon_{it}; \qquad (2)$$

- Y_{it} is the difference of numbers of off-sale general alcohol outlets in county i in year t comparing to year t-1;
- $X_{k,\,it}$ represents independent variables: difference of population, the difference of percentage of White population and Black population in county i in year t comparing to year t-1 ;
- B_k is coefficient of independent variables.
- λ is the statewide intercept;
- **T** is time as binary post-law variable (dummy), it is 1 after 1961 and 0 during years 1945-1960;
- δ is the coefficient for the binary time variable.
- μ_i is the error component allowing for counties to have a larger or smaller intercept than the statewide value λ.
- ε **it** is the error within county.

The coefficients of the above random effect model shows the difference change of numbers of off-sale general licenses over time and cross counties. The results reflect spatial and temporal dynamic difference of changing rate.

The results are reported in the RESULTS section.

Bayesian spatial - temporal Poisson regression on counts of alcohol outlets (census tract data)

Even though the limitation law is applied at the county level, county is a very large geographic region, within which variability of alcohol outlets density is high. The difference of alcohol outlets density can be huge in different parts of a county. Increasing geographic resolution to census tract level gives the model more power to discover the relationship between alcohol outlet densities with demographic and economic characteristics.

Economic theory predicts that new retail businesses will choose their location in a manner that maximizes access to potential customers relative to the local costs of doing business. It is therefore hypothesized that alcohol outlets will preferentially locate in areas with lower land and structure rents that are close to neighborhoods with greater demand (income is a surrogate for demand). Rural areas would need more small alcohol outlets to population to satisfy the sparse populated demand without high travel costs.

It is appropriate to apply Poisson regression on the counts of alcohol outlets in census tracts since there are many zeros outlet count by tract. This Poisson regression calculates rates of alcohol outlets relative to the population-based legal limits (the exposure variable). Predictors include age group, income, racial and household information etc. as well as some social-economic characteristics of the first adjacency neighbors (spatial lags). The reason to include spatial lag variables is because the outcome of alcohol outlets in a geographic unit might be affected by demands from nearby places which can be described as spatial spillover effects. For example, the richness of neighborhoods might promote restaurants to open in a nearby neighborhood with cheap rental.

Spatio-temporal distribution is captured by adding conditional autoregressive (CAR) random effects control for spatial autocorrelation of both the intercept and time trend. CAR, pioneered by Besag (1974), estimates spatial dependence of outcome due to spatial interaction of unknown variables among first order neighborhoods. It is necessary to include spatial autocorrelation in areal data analysis because spatial auto-correlation violates the standard regression assumption of independence of most standard statistical procedures (Legendre, 1993) and result in unsatisfactory regression estimates.

The model also includes a statewide time trend to allow for temporal changes in the relative rate of outlets.

The panel data for these regressions contains observations for all 7049 census tracts in California from 2001 to 2009, resulting in a space-time sample of 63,441 (i.e. 7049*9) cases. Regressions explaining on-sale general and off-sale general alcohol outlets were estimated separately using WinBUGS 1.4 software.

Below is the Poisson regression model:

$$\mathbf{Y_{i,t} \mid \mu_{I,t} \sim Poisson(E_{i,t}\ exp(\mu_{i,t}))} \qquad \mathbf{(3)}$$

Where $Y_{i,t}$ represents the count of outlets in census track i during year t and $E_{i,t}$ denotes the expected number of the outlets. This expectation assumes that outlets are distributed in direct proportion to the legal limit per capita, which is defined by population in census tracts. Hence $\exp(\mu_{i,t})$ may be interpreted as the relative rate of outlets located in census tract i at time t: regions with $\exp(\mu_{i,t}) > 1$ will have greater outlet counts than expectation based on their population, and regions with $\exp(\mu_{i,t}) < 1$ will have fewer than expectation.

$$\mu_{i,t} = \alpha + X_{i,t}\beta + t_k\theta + \pi_i + \varepsilon_i + \lambda_i t_k \quad (4)$$

Relative rates follow a Poisson distribution and therefore require generalized least squares regression (GLM) to estimate covariate effects. Therefore a log relative rate is used to model a linear combination of fixed covariate effects and random effects. These covariate effects include random effects that take into account spatio-temporal correlation. Parameter α is an intercept that controls for statewide level of alcohol outlets density rate which is not explained by other covariates. Matrix $X_{i,t}$ contains space- and time-specific covariates and β is a vector of fixed-effects parameters. θ is a linear time trend to allow for statewide growth across years $\mathbf{t_k}$. π_i and λ_i are conditionally autocorrelated random effects allowing individual tracts' intercepts and growth rates to vary around their statewide means. ε_i is non-spatial and unbiased error.

The regression is fitted using Markov Chain Monte Carlo (MCMC) iteration sampling randomly from posterior distributions based on non-informative priors and two different sets of initial parameters (Lawson, A. B., Browne, W. J., & Rodeiro, C. L. V. ,2003).

The posteriors, estimated parameters, were computed from MCMC iterations sampled after two initial-value chains were converged.

RESULTS

County Analysis: Fixed and Random Effect Linear Regressions explaining one-year difference of numbers of alcohol outlets (county data)

Result of Difference of Number of On-sale General License ($Y_{it} = \beta_n X_{n,it} + \lambda_i + \delta T + \varepsilon\ it$)

Variables	Coefficient	Std. Err.	t	P>t	[95% Conf.	Interval]
difference of population ($X_{1,it}$)	0.0001798(β1)	0.0000222	8.1	0	0.000136	0.0002234
difference of percentage of White ($X_{2,it}$)	1.775638(β2)	0.4160378	4.27	0	0.959898	2.591379
difference of Percentage of Black($X_{3,it}$)	1.047277(β3)	2.18124	0.48	0.631	-3.22956	5.324115
year 1961-2010 (**T**)	1.142346(δ)	0.5362247	2.13	0.033	0.090951	2.193742
Intercept (mean λ_i)	1.023783	0.5016338	2.04	0.041	0.040211	2.007355

Table 1– fixed effect linear regression on county panel data from 1945 to 2010

Table 1 presents the results of a county-specific fixed effect differenced linear regression model capturing the dynamic relationship over time. It shows the difference of population and difference of percentage of the White residents was both positively associated with the difference of number of on-sale general licenses. When population increased or decreased by 5561(1/ β_1), or composition of White residents increased or decreased by 0.56%(1/ β_2), there was one more or less predicted on-sale general alcohol license in the given county. On-sale general licenses appear to have grown by an average of 1.14 (see δ) more every year after 1961 in each county after controlling for population growth and difference of percentage of White and Black residents. This suggests that the law was not as effective as before it was modified in reducing the increase of alcohol outlets even though it reduced the legal limit from 1 per 1000 population to 1 per 2000 population.

Result of Difference of Number of Off-sale General License ($Y_{it} = \beta_n X_{n,it} + \lambda + \delta T + \mu_{it} + \varepsilon_{it}$)

Variables	Coefficient	Std. Err.	t	P>t	[95% Conf.	Interval]
difference of population ($X_{1,it}$)	0.0001086(β1)	8.16E-06	13.31	0	9.26E-05	0.0001246
difference of percentage of White ($X_{2,it}$)	0.8614354(β2)	0.160322	5.37	0	0.54721	1.175661
difference of Percentage of Black($X_{3,it}$)	6.386132(β3)	0.8412605	7.59	0	4.737292	8.034973
year 1961-2010 (**T**)	1.75259(δ)	0.2071749	8.46	0	1.346534	2.158645
Intercept (mean λ_i)	-0.842287	0.4413748	-1.91	0.056	-1.70737	0.0227918

Table 2 – random effect linear regression on county panel data from 1945 to 2010

Table 2 presents the results of a random effect linear regression with difference of number of off-sale general as the dependent variable. The model reveals the dynamic relationship with off-sale general licenses through time and across counties. All listed covariates have positive coefficients with the dependent variable. When and where population was increased or decreased by 9208(1/ β_1), or composition of the White residents rose or fell by 1.16% (1/ β_2), or composition of Black residents rose or fell by 0.16% (1/ β_3), the model predicts one more or one less on-sale general alcohol license. There was an average of 1.75 more off-sale general license added every year after 1961 in each county after controlling for population growth and composition difference of

White and Black residents. This suggests that the law was not as effective as before it was modified to reduce the increase of alcohol outlets even though it reduced the legal limit from 1 per 1000 population to 1 per 2000 population and further down to 1 per 2500 population.

Population Effects: Bayesian spatio-temporal Poisson regression on counts of alcohol outlets

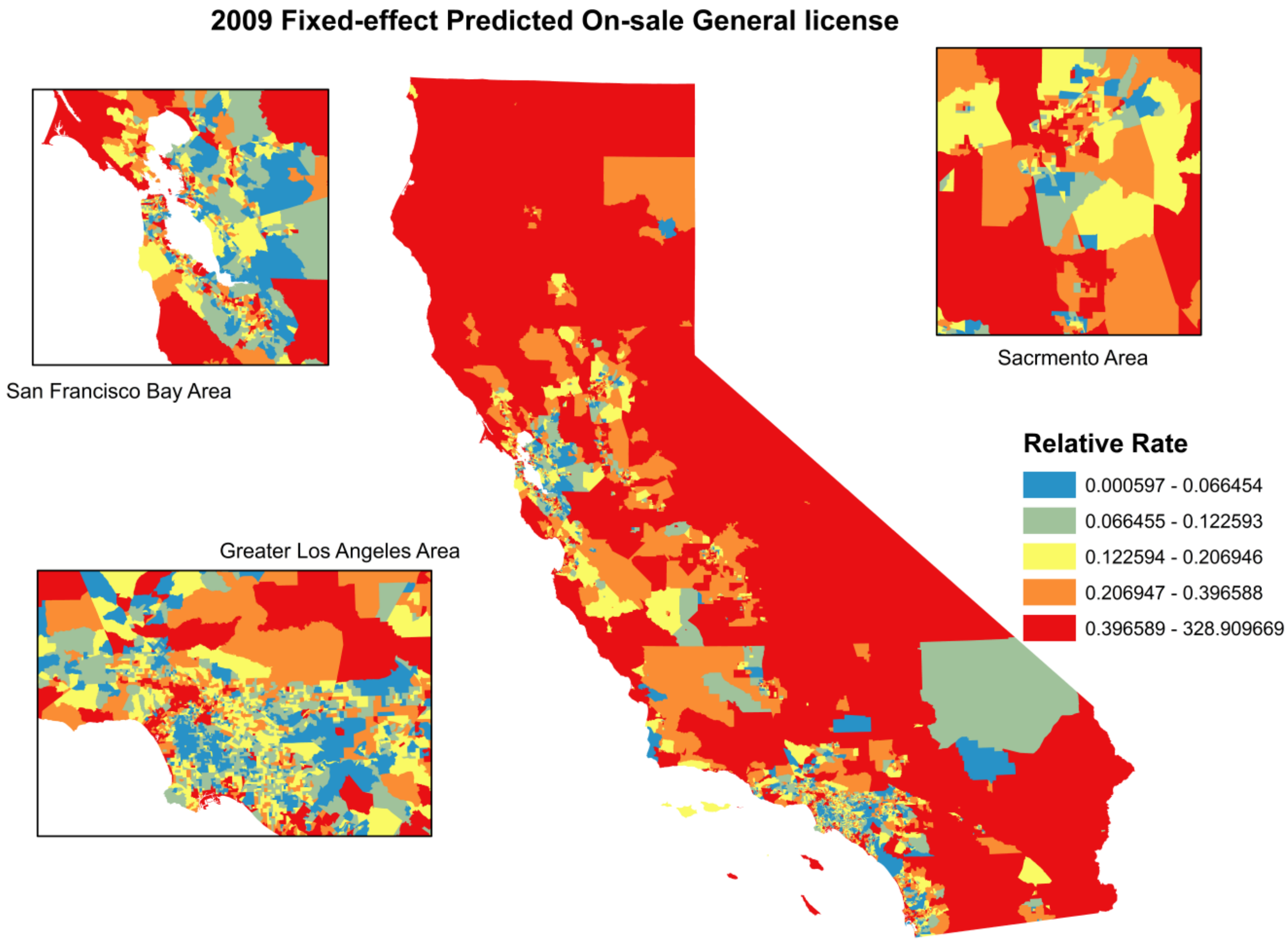
Table 3 presents a Poisson regression model explaining counts of on-sale general and off-sale general alcohol licenses relative to census tracts' population. The posterior parameters are median value of parameter distribution generated from Markov chain Monte Carlo simulation. The result is presented in table 3, along with the 95% credible interval (significant variables are represented in non-white colors). Both purple and green color indicate well supported relationship between explanatory variable and dependent variable. Purple color shows negative association while green color shows positive association. Exponential of the posterior parameter value is required for it to be interpreted as a relative rate. This table shows on-sale general alcohol outlets were concentrated in census tracts with a higher percentage of population below age 65, a higher percentage of population below 150% poverty, a higher vacant house rate and a lower percentage of Black residents, a lower percentage of households with children under 17, a lower percentage of Hispanic residents, a lower median household income and a lower population density. Over time, the trend shows there was a slight increase of on-sale general alcohol outlet density each year even after controlling for other covariates. The random effect regarding spatial auto-correlation explained 51% of overall unexplained on-sale general alcohol outlets densities. Moran's I coefficient of the spatial autocorrelation random effect is 0.82 which indicate the CAR random effects are highly spatially autocorrelated.

Off-sale general alcohol outlets were more concentrated in census tracts with a great Hispanic population percentage, a greater percentage of population under 150% poverty level, a lower median household income, but a higher median household income in adjacency neighbors, a higher vacant house rate, a lower percentage of population below 65 years of age, a lower percentage of households with children under 17, a lower percentage of Blacks and Asians, and a lower population density. There is no well-supported trend over time. The random effect of spatial auto-correlation explained 17% of overall unexplained off-sale general alcohol outlets density. Moran's I coefficient of the spatial autocorrelation random effect is 0.96 which indicate the CAR random effects are highly spatially auto-correlated.

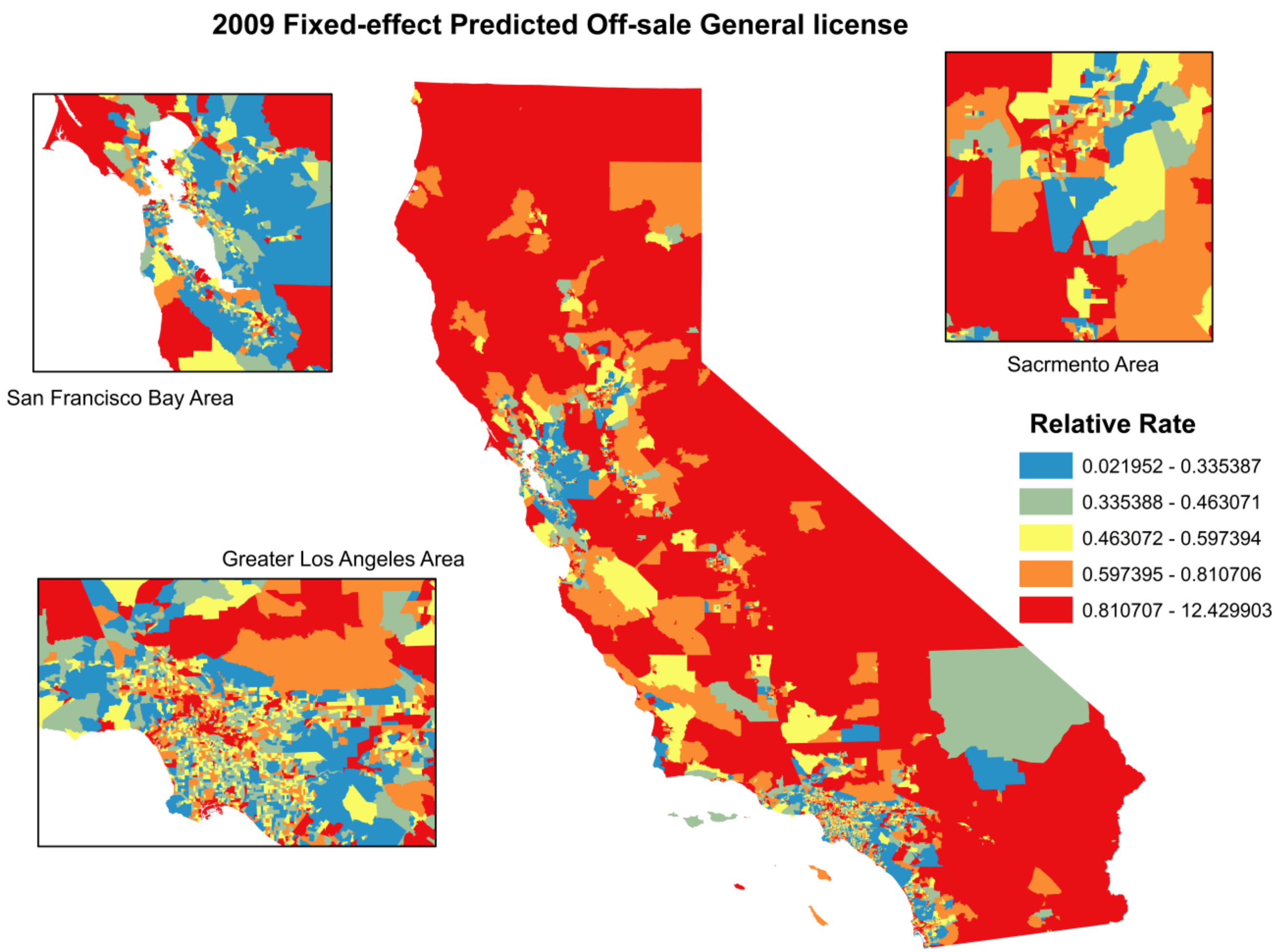
Relative Rate from Poisson Analyses explaining outlet counts relative to population

	On-sale General				Off-sale General			
Variable	**median**	2.50%	97.50%	**RelRate**	**median**	2.50%	97.50%	**RelRate**
pct of ASIAN	-0.003911	-0.00999	0.001696	0.996096638	-0.007924	-0.01213	-0.00438	0.992107
pct of BLACK	-0.04047	-0.04803	-0.03229	0.960337974	-0.008323	-0.01296	-0.00369	0.991712
pct of HISPANIC	-0.005362	-0.00891	-0.001337	0.99465235	0.005139	0.002518	0.008893	1.005152
Median Household Income(x1000)	-0.005836	-0.00775	-0.003413	0.994180996	-0.01453	-0.01654	-0.01132	0.985575
pct of household with children under 17	-0.06721	-0.07232	-0.06198	0.934998831	-0.02573	-0.0313	-0.0229	0.974598
population density(1000/m^2)	-0.05998	-0.06818	-0.05299	0.941783369	-0.02335	-0.02845	-0.01728	0.976921
pct of population below 150% poverty	0.03316	0.02919	0.0375	1.033715921	0.01355	0.01019	0.01765	1.013642
unemployment rate	0.0005867	-0.00286	0.004046	1.000586872	-9.43E-04	-0.004673	0.002909	0.999057
vacant rate	0.03136	0.02278	0.04126	1.031856906	0.006926	0.0011	0.01307	1.00695
pct population age 0-19	0.03185	0.02712	0.03692	1.032362639	-0.01012	-0.01689	-0.0028	0.989931
pct population age 20-24	0.01787	0.01159	0.02347	1.018030624	-0.01346	-0.02075	-0.00565	0.98663
pct population age 25-44	0.02051	0.01681	0.02399	1.020721775	-0.008693	-0.01326	-0.00431	0.991345
pct population age 45-64	0.01542	0.01109	0.02085	1.015539502	-0.01253	-0.01713	-0.00678	0.987548
first neighbor Median Household Income(x1000)	-6.41E-04	-0.00355	0.001688	0.999359006	0.007825	0.005137	0.00981	1.007856
first neighbor population density(1000/m2)	0.0007358	-0.00054	0.001993	1.000736071	1.78E-04	-0.001277	0.00159	1.000178
first neighbor pct of population below 150% poverty	0.00003822	-0.00056	0.0006328	1.000038221	-1.00E-04	-6.96E-04	5.01E-04	0.9999
first neighbor unemployment rate	-0.001663	-0.00638	0.002919	0.998338382	3.18E-04	-0.004224	0.004986	1.000318
Constant	-0.8794	-1.23	-0.5766	0.415031856	1.484	1.027	1.833	4.410553
Time trend	0.01334	0.006078	0.01908	1.013429375	-0.005107	-0.01155	0.003446	0.994906
carvariance ratio	0.5079	0.4185	0.5945		0.1737	0.1085	0.2366	
tau.delta	1583	1035	2698		9667	5869	17900	
tau.u	0.2738	0.2074	0.3671		2.308	1.597	4.114	
tau.v	0.2828	0.2586	0.3108		0.4846	0.4588	0.5115	

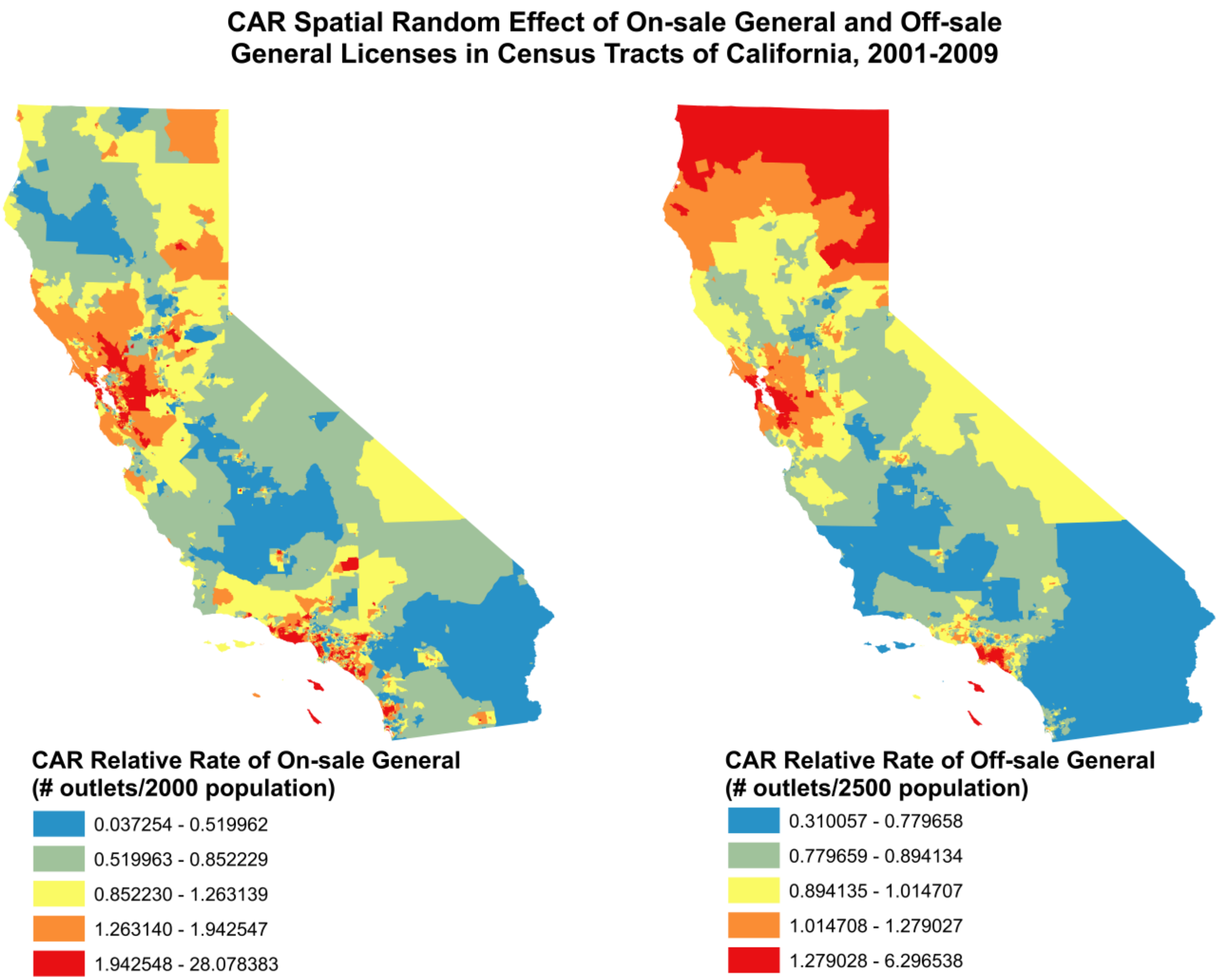
Table 3 – Results of Poisson regression of census tract panel data



Map 1 - Expected relative rate of on-sale general alcohol outlets to population in 2009



Map 2 - Expected relative rate of off-sale general alcohol outlets to population in 2009



Map 3 - Spatial auto-correlation of unexplained alcohol outlet relative rate to population

Map 1 and Map 2 display the relative population rates of on-sale and off-sale outlets, respectively, predicted from fixed effect combination of social-economic variables in 2009. Map 3 is the unexplained spatially auto-correlated relative rates from these analyses, and therefore identifies regions that have higher outlet densities than would be expected based on their measurable characteristics. All the maps were symbolized with quintile classification. Yellow contains the average relative rate. Red are census tracts with much higher relative rate than average. Blue are census tracts with much lower relative rate than average. Even though urban area of San Francisco Bay area and greater Los Angeles area were predicted to have low on-sale general and off-sale general alcohol outlets to population based on their socio-economic characteristics (see Map 1 and Map 2), Map 3 shows that these specific regions had higher alcohol outlets density in reality. The CAR spatial auto-correlation model (see Map 3) was able to pick up the phenomenon that San Francisco Bay area and greater Los Angeles area had higher than expected outlet densities, perhaps reflecting their status as major tourist destinations.

DISCUSSION

Graphs 1 and 2 show that the average on-sale general and off-sale general alcohol outlet densities in counties were decreasing slowly since the 1940s. It was a slow adjustment over time despite the alcohol outlet density limitation laws. The law only has the authority to regulate on new applications and transfer into licenses below limits and it does not have the privilege to close any previous open stores. Even though the legal limit was reduced to be more restricted, it did not efficiently control the increase of alcohol outlets than before (see from δ in Table 1 and Table 2). Surprisingly, the new legal limits appear less effective than old ones in reducing the increase of alcohol outlets. One possible reason would be some counties were allowed to have more than limited alcohol outlets due to public demand and convenience after 1961. It may also be that the influence of economic or demographic variables that could not be controlled in these analyses due to lack of census data back to 1940. The results could be much more meaningful if ethnicity, economic, alcohol consumption, industry and road network variables are taken into account in the analysis.

Table 3 shows numbers of both on-sale general and off-sale general alcohol outlets relative to population were consistently higher in census tracts that were less densely populated, lower percentage family oriented, lower income, higher vacancy house rate, higher percentage of population under 150% poverty level and lower percentage Blacks. The difference is for on-sale general alcohol outlets, the densities are higher for younger populations (below age 65) and lower for Hispanics; while for off-sale general alcohol outlets, the densities are lower in younger populations (below age 65), higher among Hispanics, lower among Asians and higher in neighborhoods adjacent to higher incomes.

The Poisson model revealed social disparity in poor neighborhoods. Neighborhoods with low median income, high percentage of population under 150% poverty level and high vacancy rates have high alcohol outlet densities. Especially those adjacency to rich neighborhoods have even higher off-sale general alcohol outlet densities. It suggests that off-sale general alcohol outlets preferentially open in poorer neighborhoods that are near to higher-income populations that can afford to buy more alcohol. This confirms the economic theory that retail businesses choose their location in a manner that maximizes access to potential customers relative to the local costs of doing business. The limitation on alcohol outlets at the county level cannot address social inequality in smaller geographic region.

The percentage of Black residents was negatively associated with alcohol outlets density. This can likely be explained by Consumer Expenditure Survey findings for 2011-2012 showing that Blacks and Asians spent a much lower percentage of income on alcoholic beverage than did Whites (0.5% VS 1%).

The Poisson model with the legal limits of given population of the exposure variable, estimated a negative relationship between alcohol outlet and population density. From map 1 and map 2, it also seems that rural areas had higher relative rates of on-sale general and off-sale general alcohol outlets to population. It can be explained by smaller outlets required to satisfy a dispersed population. It is idealistic to have one universe limitation statewide in California since the heterogeneous characteristics of people and land. The fact is that a series of exceptions were introduced in Statutes allowing low populated counties to have more than limited alcohol outlets.

The ratio of number of alcohol outlets to population cannot reflect alcohol availability to the population. There are huge variance among different alcohol outlets. For example a big liquor store can hold multiple times of liquor than a small one. And outlets locate at a convenient location in the context of transportation network can satisfy much more population than an inconvenient one. With restocking supply chains more efficient than ever ‘small’ outlets have lost the tradition meaning and can compete with big liquor stores. The alcohol outlet density is not proportional to the sale of alcohol.

In the results of spatial Poisson regression model, the CAR regression model (see Map 3) was able to pick up this heterogeneity such as the San Francisco Bay area and the greater Los Angeles area that had higher than expected outlet densities, perhaps reflecting their status as major tourist destinations. It made the prediction more accurate and unbiased in different area.

The Poisson spatial regression model was estimated using Bayesian analysis instead of frequentist method in this study. The Bayesian approach is flexible and allows prior belief of the data taken into account in calculating posterior estimates. (Dormann et al., 2007). The Poisson spatial regression code applied in WinBUGS is provided as an electronic appendix.

CONCLUSION

This research showed the temporal and spatial distribution of alcohol outlets in California. The descriptive statistics showed the general trends of alcohol outlets density were declining. The fixed effect linear regression captured the temporal dynamic of on-sale general alcohol outlets. It revealed the number of on-sale general alcohol outlets increased with population and percentage of Whites. The random effect linear regression on off-sale general outlets explained the impacts across county and time. It recovered the number of off-sale general alcohol outlets increased with population, percentage of Whites and percentage of Blacks. The time dummy variables in the fixed and random effect models showed that the reduction of limitation on alcohol outlet density did not control the growth of alcohol outlet more efficiently. The Bayesian spatial-temporal Poisson regression on census tract panel data discovered the social disparity in poor neighbors especially those adjacenct to rich neighbors. Spatial auto-correlation random effect in Poisson regression explained 51% of overall errors that could not be explained by neighborhood characteristics for on-sale general alcohol outlet density, and 17% for off-sale general alcohol outlet density. Without the spatial auto-correlation, the results will be biased due to the dependency between adjacent neighborhoods. It is important to include spatial auto-correlation when analyzing data that vary by geography.

The alcohol outlets density law is not efficient in reducing the numbers of alcohol outlets. And the regulation in county level cannot address social inequality issues.

APPENDIX

Links of WinBUGS code for Bayesian Spatial Poisson regression in the thesis:

https://drive.google.com/file/d/0BzSEm5q6F1AaaHlZN3Vmb3BMY0k/view?usp=sharing

https://drive.google.com/file/d/0BzSEm5q6F1AaeTFsQ05HRkM0LWM/view?usp=sharin

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